Art. IV.—*Electric Lighting.*

By R. E. Joseph.

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A few months back, in a paper read before you, I briefly reviewed the progress and improvements that had taken place in electric lighting, and then promised to lay before you, at a future time, further information on the subject. In my former paper I gave you an account of the principal machines used in generating currents, of the lamps in use, and the adaptation of different systems for various requirements. Since then certain changes that have taken place, not so much in the construction of the apparatus as in the methods of using them, have necessitated a slight alteration in my views on the matter. Commencing with generators of the current, the battery appears to have remained in exactly the same position as before, and I am not aware of any improvements having been made in any of the numerous forms, to render it a useful agent for electric lighting. In dynamo-machines the principle of construction remains the same; very little, if anything, has been done to render the machines more efficient. As a proof of this, the Siemens, Gramme, and Brush, which were spoken of as giving the best results, still hold the foremost position amongst the now numerous descriptions of machines. The original Siemens machine gives now, as before, a very high per centage of useful work per horse-power, followed, however, very closely by the Gramme. Since my former paper some twenty or thirty new descriptions of dynamo-machines have been introduced, but a very slight examination shows that they are all constructed on either the Siemens or Gramme principle, and that if they possess any advantage over them, it is, in most cases, in mechanical details, such as simplifying their manufacture, reducing the tendency to over-heating, and arrangements of certain parts to facilitate cleaning, &c. There are, however, one or two exceptions in which a very high amount of efficiency has been obtained, with the use of less wire on the revolving coils than usual; this extra efficiency being gained by the methods of arranging the coils, and also by placing nearly the whole of the wire in the magnetic field. Amongst the most prominent and successful of these modifications are the Weston, Burgin, and Schukert machines. The Weston has a Siemens armature, but contains half the number of coils on its circumference, the place of the wire being taken by soft iron, and the wire itself laying in a channel surrounded by soft iron, has its inductive effects considerably augmented. The Burgin is a combination of the Siemens and Gramme. The revolving bobbin is long,like the Siemens, but it is built up of a series of rings, wound something like the Gramme, and connected together. The Schukert is a Gramme ring, but exposes nearly the whole of the wire in the magnetic field. Dynamo-machines are now required, giving two different kinds of current—low tension for single, and high tension for multiple arc lights. The low tension is of course easily attainable, large wire and low speed, giving a very large current of very low tension. The most remarkable description of machine of this kind is Edison's, the armature being built up of bars of copper, having practically no resistance whatever, driven at a speed of 350 revolutions per minute, it is stated it will supply sufficient current to maintain 1000 incandescent lamps of about seven candle-power each, all joined up of course in parallel circuit.

To obtain currents of high tension is not so easy. With the present system of generating currents, it is attained by either decreasing the size of the wire on the bobbins and increasing the number of convolutions, or by increasing the speed of rotation. In the first instance the trouble of heating and destroying the coils makes its appearance, and in the second the difficulties of mechanical construction—that of making the revolving bobbin in such a form as to be perfectly secure, and to prevent the wire flying off when revolved at very high speeds. Consequently, up to the present time, the highest tension current machine made is that of Brush, capable of supporting forty arc lights on one circuit.

The armature is a modification of the Gramme ring, and contains a very large quantity of wire wound in spaces cut out of the iron ring. Special precautions are taken to prevent cross-currents being generated, and for keeping the armature cool. The wire coils pass very close to the pole-pieces of the field-magnets, the very excellent workmanship shown in the construction of the machine enabling this to be done with safety. The commutator is so arranged as to supply a current to excite the field magnets without passing into the outside circuit, whilst it also cuts out all coils that are not used in generating a current, thus reducing the resistance of the machine. In other machines the same end is obtained by using a separate machine to excite the field-magnets of the generator; this, whilst keeping the field-magnets in perfectly uniform condition, lowers the resistance and increases the electro-motive force to a considerable extent. The question, however, arises as to the advisability of using machines of high tension. Looking at electric lighting as a thoroughly practical means for illumination, it appears certain that it will be necessary to maintain a considerable number of lights on one circuit. I refer now to arc lights. The difficulties I mention do not apply to the same extent to the incandescent lamp. In the earlier days of electric lighting, where instalations were used in certain buildings only, lights fed from single machines were found convenient, and unquestionably the most economical for very powerful lights. When, however, the method of lighting from a central station and supplying a very great number of lights distributed at various distances from the generator had to be determined, it became evident that it would be impossible to carry it out by the same system. The immense number of conductors required would alone be sufficient to condemn it, apart from the cost of attendance to the number of machines that would be in use. Therefore, systems capable of supporting a number of lights from one machine rapidly gained public favour, and the system that could support the greatest number of lamps in the same circuit has commercially been the greatest success. But has this advantage been gained in a right direction? and if the present system be adhered to, does it not amount to either a limit to the number of lights to be used or the introduction of machines which for safety to human life are hardly to be desired. The original dynamo-machines constructed to generate low tension currents are perfectly harmless, the current may be conducted by imperfectly insulated conductors, as in the instance of the Berlin electric railway, where the iron rails laid on wooden sleepers are the only conductors used, and they answer perfectly even in wet weather. A person coming in contact with the wires or any portion of the apparatus might, and probably would, detect the presence of a current, but that is all; so that for safety and facility for conducting the current, the low tension was all that could be desired. But then it became clear that if a considerable distance intervened between the lamp and the machine, a very large conductor became necessary, whilst if more than one light was required on one circuit, the low tension current failed to support them. Consequently the tension of the current was increased in proportion to the number of lights required to be maintained, or for the distance the current had to pass between the machine and lamp, and attended with the usual characteristics of currents of this nature.

The insulation of everything in connection with the circuit has to be most carefully attended to; and such insulation requires to be of a very high nature, or failures must occur. The recent failures of the Brush system in London, Edinburgh, and elsewhere, have all been traced to imperfect insulation of the circuit, and if it has been found difficult and expensive to provide a perfect insulation for a current supporting from 30 to 40 lights, those who are familiar with the behaviour of high tension currents will at once realise the state of affairs, if machines were made to support, say, even 100; and with the difficulties of insulation comes the dangers from fire, and loss of human life. With a badly insulated conductor from such machines, fires have occurred undoubtedly; whilst there have also been several instances recorded of fatal accidents occurring through the same cause, and although, by taking careful precautions, the risks of mishaps may be reduced to a minimum, they are always liable to occur, and with any increase in the tension of the current, probably would constantly occur. It would therefore appear that machines capable of supporting, say, from ten to fifteen powerful arc lights, are the largest that should be used, both for safety and certainty in working, as long as high-tension currents are required for such purpose. This would therefore point to the conclusion, that, for successful and commercial electric lighting, we should look in another direction, even if we have to re-arrange the whole of our present system of working.

Since writing this I have come across a paper read by Mr. Swan, before the Royal Institution, and printed in *Engineering* for March, and in which the following paragraph appears :—"Can electricity be distributed as widely and cheaply as gas? On one condition, which I hope can be complied with, this may be answered in the affirmative. The condition is that it be found practicable and safe to distribute electricity of comparatively high tension."

It will thus be seen that Mr. Swan assumes that a high-tension current is absolutely necessary for an extended and economic distribution of the current, and with our present method of working, there is very little doubt that his views are correct. I am, however, of opinion that, instead of endeavouring to perfect any system which requires for its success the employment of such currents, we should turn our attention to obtain the required results by the safe and easily worked low-tension current.

Respecting arc lamps, I have little to add to my former remarks. Their construction has been considerably simplified, and by this means several difficulties formerly experienced in their working have been removed.

The specimens before you this evening are the "Siemen" pendulum and differential lamp, fitted with Dr. Siemen's abutment pole, for burning from fourteen to nineteen hours; the "Brush," double rod, burning sixteen hours; and the "Weston" lamp, slightly modified and manufactured in the colony. The last two lamps contain no wheel work or delicate mechanism to feed the carbons, the regulation being effected solely by electro-magnets so arranged that the proper length of arc is maintained by means of a shunt of fine wire placed in circuit between the two carbons, and acting in an opposite direction to the main wire coils. The arc light remains as before the most economical means of illumination for large spaces, a light of about 3000 candle-power being maintained by an efficient dynamo-machine, and driven by a gas-engine consuming about sixty feet of gas per hour, or as much as would suffice for the support of from twelve to fifteen gas-jets for the same period, and when it is borne in mind that gas costs three times as much as coal for an equivalent amount of power, the economy of the arc light becomes at once apparent. The Jablochkoff candles still maintain a prominent position in electric lighting on the Continent; but beyond lighting part of the Thames embankment, London, the system does not appear to have made much progress in England. Semi-incandescent lamps also do not make very much headway. One that has been prominently before the public for some time is the Joel incandescent lamp, and consists of a slender pencil of carbon, the point of which impinges on a copper button. The success it has met with is not due to the principle, which is old, but to the thought and care bestowed in carrying out mechanical details of construction in rendering the lamp certain and automatic in its action.

The use of powerful currents demands a special system of testing. The ordinary methods adopted for battery-testing cannot always be conveniently used, although of course they are the most reliable; but as all of them would involve the use of shunts and a very delicate apparatus, special galvanometers or dynamometers have been introduced, which give fairly approximate measurements. Siemen's dynamometer consists of a coil of wire through which the powerful current is sent, and passes by means of mercurial contacts through a rectangular frame of stout copper wire, suspended by a spiral steel spring at right angles to the wire coil. The instrument being set at zero, the current will deflect the wire-frame, the opposing force being the torsion of the spiral spring. The angle of torsion through which the spring has to be moved in order to bring the wire frame to its zero point, can be read off on the dial, and its value having been previously determined by experiment and a table prepared, the amount of current in ampères flowing through the instrument can at once be ascertained. The accuracy of this instrument depends entirely on the stability of the spiral spring; and in order to render it as stable as possible, it is made of finely tempered steel wire and then gilded.

The absence of permanent magnets in this instrument renders it of use for measuring alternate currents, for which purpose another coil of thinner wire is provided. Another form of galvanometer, lately introduced by Professors Perry and Ayrton, is a modification of the Desprès galvanometer, in which a very small compound magnet needle is placed in the field of a powerful permanent horse-shoe magnet. The needle is also in the centre of a small wire coil, constructed of a strand of ten wires, and so connected with a commutator that the current can be either sent in parallel circuit —that is, with the wires joined together at each end, and representing a short and thick wire—or in series, which would be the wire joined in continuous circuit, of one-tenth the size, but ten times as long as in the former case.

The action of this galvanometer renders the needle perfectly dead beat, returning to zero quickly, whilst the proportions of the instrument are so arranged that the amount of current passing can be read off in ampères without the aid of tables, and by the double arrangement of the wire-coil the galvanometer is ten times more sensitive when joined up in series than in parallel circuit, thus rendering the instrument available for the measurements of small currents. Perry and Aryton's galvanometer has the advantage of being portable, and is sufficiently accurate for ordinary testing or ascertaining the amount of current passing through an electric light circuit. It is particularly valuable in incandescent systems, because it becomes absolutely necessary to keep the current constant and steady, and with such a galvanometer in circuit, any alteration in the current strength can at once be seen. For a temporary instalation of the electric light, and where an engine not specially adapted for driving dynamo-machines is used, the galvanometer, if placed near the engine-driver, serves the purpose of an auxiliary governor. The engine-driver watches the galvanometer needle, and having been directed to keep it at a certain position, increases or diminishes the speed of the engine according to any alteration in the galvanometer. This method answered perfectly well recently at a lecture given at home, the steady working of the Swan lamps shown there being entirely governed by the above arrangement.

In my former paper I spoke with great distrust of Edison's attempts at incandescent lamps. I felt justified in the remarks then made, because really nothing but failures had been recorded against him. Since then he has unquestionably achieved a success, and produced an incandescent lamp, which is stated to be quite equal to that of Swan. The specimens of lamps before you are the "Original" and "New Swan," the "British," and the "Maxim." These lamps are similar in construction—a fine carbon loop in an exhausted and hermetically sealed glass bulb. The Swan carbon is prepared from ordinary crotchet cotton, treated with sulphuric acid and carbonised. The Maxim is made out of cardboard. Edison's is constructed from bamboo fibre, so that they may all be classed as the same—all being converted into carbon. But whilst their construction is apparently the same, their behaviour and endurance differs slightly. Thus the old Swan lamp should not be pressed beyond fifteen to twenty candle-power, when it will last about 600 hours. The new form has lasted over 1000 hours. The Edison lamps must not be pressed beyond seven candle-power, whilst the Maxim ranges from twenty-five to eighty candle-power, absorbing, of course, a larger, but not proportionately larger, amount of current. The incandescent lamp, whilst not being nearly so economical as the arc light, possesses advantages that would more than compensate for this deficiency. It may be accepted, I think, as a fair average that about 200 candle-power per horse-power can be obtained from incandescent lamps, everything being in its highest state of efficiency; but it probably will be found with respect to endurance that from 120 to 150 would produce the most economical results. Probably one of the most peculiar features about the carbon loop is the alteration in its resistance when heated. It is of course well known that increase of temperature in metals increases their resistance; with the carbon loop it is different, increase of temperature reducing the resistance to a remarkable degree, in some cases as much as 60 per cent. A Swan lamp with a resistance of 65 ohms when cold, will only have a resistance of about 37 when heated to incandescence. The current necessary to maintain a Swan lamp of about fifteen candle-power is 1·25 ampères, with an electro-motive force of forty volts. It will thus be seen that certain arrangements have to be made in placing a number of incandescent lamps in circuit. They are arranged usually as parallel, compound parallel, and in parallel series circuit, according to the resistance of the lamps and the machine supplying the current. No difficulty need therefore be experienced in working any number of incandescent lamps from very large dynamo-machines of low tension.

For purposes of regulation, two or three methods present themselves as being efficient—by interposing a high resistance in the leading circuit, by alteration of the position of the brushes on the commutator of the machine, or by interposing a resistance in the circuit of the field-magnets when a separate exciter is used. By this means less power is absorbed, and, consequently, it is the most economical.

Incandescent lamps can be supported by either continuous or alternate currents, by either high or low tension, so that almost any kind of machine can be adapted to them.

That the successful introduction of incandescent lighting will cause a revolution in ordinary systems of illumination is now, I think, quite evident. Even in its present stage incandescent lighting has commenced to play an important part, and is being rapidly introduced for lighting places of amusement, churches, and large establishments, whilst nearly every modern steamship has been, or is being, fitted up with one of the systems.

With respect to the economy of the incandescent lamp, I think it can be shown that even at the present time the cost of producing an equal amount of illumination will not exceed that of gas.

A ton of coal will, I believe, produce 10,000 cubic feet of gas—enough to supply 2000 good gas burners for one hour. A ton of coal burnt in the steam-engine will produce 748 horse-power and will support 7460 incandescent lamps of the same power as the gas burner for the same period of time. I have only estimated the horse-power at 3 lbs. of coal per hour, but in an extensive system of lighting to take the place of gas the amount of coal used per horse-power would not be so much. I think on board some of the large steamers from 1½ to 2 lbs. of coal per horse power per hour is all that is used; but, as in the manufacture of gas the residue of the coal yields products of great value. I have quoted the larger amount as a set off.

The cost of manufacture, wear and tear, &c., should not be more in the one case than the other; whilst the distribution would be in favour of the electric lamp; whilst the cost of renewals would not amount to anything like the difference shown to exist between the two systems.

Taking another example. Twenty-five cubic feet of gas will produce one horse-power in a gas-engine for one hour, and thus support ten incandescent lamps; whilst the same amount of gas burnt would only suffice for five burners of equal illuminating power. I have not in this paper treated on the subject of secondary batteries or accumulators, neither having spare time to make any experiments in this direction, nor information of a reliable nature to show that their use in electric lighting has been extended beyond the lecture-room or for experimental work.